for Lake Michigan-Huron, about 24.7 inches; for Lake Erie, about 30 inches; for the vicinity of Boston, about 28.5 inches; for Lake Tahoe, Calif., (altitude 6,230 feet) about 22 inches; for Great Salt Lake, Utah (altitude 4,200 feet) about 26 inches.

DISCUSSION

By C. F. MARVIN

Perhaps there is no measurement of a meteorological phenomenon concerning which there is greater diversity of view than prevails with reference to evaporation from free water surfaces. The Weather Bureau, in choosing the present so-called standard type of evaporation pan, fully considered practically all the faulty characteristics pointed out by Mr. Grunsky.

In reaching our decision we are compelled to recognize that the observations must be continued, not for a few weeks or months, but over periods of several years of time, and under the care of observers who are often conscientious enough but, nevertheless, lack the highly trained character of engineers or laboratory physicists whose minds are always alert, as to sources of error and fallacious records. In the case of pans floating in water or pans buried deeply in the ground, it is almost surely a question only of time before an insidious leak develops in the seams, or even in the body of the pan itself, out of which water passes in unknown quantities, always measured as so much evaporation. Maintenance of a proper condition of cleanliness is difficult, unless the pan can be thoroughly washed and rinsed, a process much simplified when the water can be poured out.

Mr. Grunsky's criticism that the Weather Bureau type of pan is so freely exposed to the air, even underneath, that its temperature fluctuates widely, is true, but this construction is one that permits of the discovery of leaks and faults of the apparatus that perhaps might otherwise escape the notice of a careful observer.

Moreover, the conditions that surround the standard Weather Bureau pan undoubtedly lead to a larger quantity of evaporation than that representing conditions over large, free surfaces of reservoirs, lakes, etc. However, this larger evaporation admits of a more accurate measurement, and its subsequent correction is a subtractive reduction of the actual observation, involving in principle a greater accuracy than would otherwise be the case; that is, the engineer in using these data is on the safe side, inasmuch as the evaporation may be really less than that estimated from the observations.

While these remarks are applicable to the Weather Bureau practice, there is a full realization of the decided advantage of making evaporation measurements that require no consequential correction of any kind. However, this concept presupposes that the evaporation characteristic of a given climate is a definite and constant thing for all possible utilization, such, for example, as the water losses from open reservoirs, water losses from vegetation by transpiration, forest cover, etc. Each of these uses of the evaporation characteristic of a given locality is contemplated in the data being collected by the Weather Bureau, and while our results may have a limited value for determining the exact evaporation from a free reservoir surface, they may have greater value for other uses.

RELATIVE FREQUENCY OF CENTERS OF CYCLONES AND ANTICYCLONES IN THE UNITED STATES

ERIC C. MILLER

Weather Bureau, Madison, Wis.

Cyclones and anticyclones are difficult to deal with statistically, hence have not received attention in proportion to their importance as climatic elements. This paper attempts what may be called a "census" of the number of centers that appear in each 5° square of latitude and longitude, at the 8 a. m. and 8 p. m. (eastern standard time) observations, per month and per annum.

In order to eliminate the varying lengths of the months, the monthly data have been reduced to the number of occurrences per 1,000 observations. For the year, the number of centers per annum per 5° square are given here.

The monthly and annual statistics have been entered at the center of each square, and lines of equal frequency drawn. Graphs showing the march of frequency through the year have also been drawn for each square, and these have been transferred to maps of the United States on the Mercator projection, so that each square is of the same width in longitude.

Before enumerating the results of this study, it must be pointed out that these statistics differ from those of Garriott (1) and Kullmer (2), which show the number of centers that passed across the individual squares. The present paper counts only those centers that were in the square at the two daily observations.

The charts and graphs accompanying this paper show that—

(1) The number of centers, of both cyclones and anticyclones, is greater in the interior of the continent than around the margins. Mark Twain, in a famous after-dinner speech (3) has called attention to the variability of New England weather. These charts show more than twice as many centers over the Great Lakes and the Plains as in New England. Success in weather forecasting (4) is negatively correlated with the number of centers, and is at a minimum in the Lake region.

(2) A center of maximum frequency of cyclones exists in Saskatchewan at all seasons.

(3) There is a maximum of frequency of cyclones in the Lake region in July and August, in the West Gulf States in January. The intervening States show two maxima, one in spring, another in autumn, corresponding to the popular tradition of the "equinoctial storm," and also to two maxima of rainfall; e. g. in eastern and southern Wisconsin. Whether there is continuous travel of a "polar front," or tendency to steep temperature gradients, back and forth from the 30° parallel to the 50° parallel of latitude, may be worth investigating.

(4) In winter, a loop of maximum frequency of anticyclones extends from Saskatchewan to the southern Appalachians.

(5) Centers of anticyclones have a maximum of frequency in Oregon and Washington in summer, when the semipermanent anticyclone in the Pacific is at its greatest intensity.

(6) Maxima of frequency of anticyclones appear successively in contiguous regions as follows: July to

September in the Missouri Valley, Central Rocky Mountains in October and November, and in the northern Plateau region in December and January. The high frequency in October in the Southwest is especially noteworthy, and its cause needs investigation.

(7) The Great Lakes have a well-defined maximum of anticyclones in August, when the lakes are cooler than the surrounding lands, and a minimum in winter when warmer than the surrounding lands. The influence of these lakes on cyclones and anticyclones has been discussed by Cox (5).

(8) The all-year minima of frequency of both kinds of centers in California, Florida, and along the southwestern border from Texas to Arizona, are important climatic influences in making those regions winter resorts.

The data used in this paper were obtained from the well-known papers by Bowie and Weightman on types of storms and of anticyclones of the United States and their average movements (**6**, **7**) for the 21 years 1892–1912 inclusive. In the papers of Bowie and Weightman, the centers were kept separate according to region of origin, and their "types" refer to region of origin. Here all types have been added together, hence there remains in the present paper no differentiation with respect to type. All that is assumed is that Bowie and Weightman included all centers in their statistics. Nothing of their method of compounding 24-hour movements of centers to obtain the average movement enters into the present paper. It seems important to emphasize these points, inasmuch as Garriott (**1**) drew a free-hand curve through the squares having the greater number of cyclones passing through them, determining branches and branch points more or less arbitrarily. These so-called "storm tracks" have enjoyed a vogue entirely out of proportion to their merit. Bigelow (**8**) published maps of storm tracks, apparently without any numerical basis. Van Cleef (**9**) has shown by the logical process of *reductio ad absurdum* that there is no type storm and no typical storm track, but his charts have been used by others as illustrations of typical storm tracks. Let it be understood, then, that this paper deals solely with the "census" of centers of cyclones and anticyclones, on the basis of observations twice a day, during the 21 years, 1892–1912 inclusive. The monthly charts have been reduced to the number of centers per 5° square per 1,000 observations by dividing the observed numbers by 1,302 for 31-day months, 1,260 for 30-day months, and by 1,186 for February. The graphs of march of frequency show the same data as the monthly charts. The charts of annual totals have been reduced to a basis of one observation per day by dividing the totals for 21 years by 42.

TABLE 1.—*Relative frequency of centers of cyclones pro mille of observations per 5° square*

Latitude	Longitude	January	February	March	April	May	June	July	August	September	October	November	December
° °	° °												
50-55	80-85	2	1	------	------	1	2	2	2	1	4	3	0
	85-90	6	6	5	------	2	2	12	5	9	8	5	4
	90-95	5	6	5	4	5	6	19	12	6	8	11	7
	95-100	26	18	18	17	15	17	27	27	29	28	24	28
	100-105	35	27	17	25	25	36	31	41	36	32	39	35
	105-110	40	32	28	33	33	44	32	35	38	41	42	45
	110-115	48	44	45	48	40	56	36	35	44	46	53	58
	115-120	27	24	24	30	18	27	18	25	28	30	31	33
	120-125	10	14	18	13	9	5	6	11	17	15	21	21
45-50	60-65	2	2	2	------	------	2	------	1	0	3	4	0
	65-70	11	8	11	9	8	13	15	10	1	12	10	10
	70-75	19	1	12	10	18	31	26	28	12	20	17	12
	75-80	34	20	22	21	24	21	34	38	24	21	29	27
	80-85	43	26	24	22	31	28	31	41	28	41	44	41
	85-90	44	34	28	38	36	38	49	52	48	48	49	45
	90-95	27	22	21	28	17	30	32	38	34	35	35	33
	95-100	28	19	22	28	26	33	38	40	40	34	38	31
	100-105	20	10	14	21	21	45	35	39	33	25	22	19
	105-110	13	14	24	20	22	25	31	37	31	23	20	15
	110-115	16	12	12	17	24	18	13	24	14	9	19	12
	115-120	13	4	8	13	12	10	12	16	11	5	21	6
	120-125	27	24	25	14	8	9	0	2	7	15	27	26
	125-130	27	19	15	5	5	2	0	0	6	10	24	25
40-45	60-65	8	7	+1	2	1	2	0	0	0	3	4	2
	65-70	18	17	10	7	8	3	8	7	0	15	21	24
	70-75	17	11	21	22	18	6	15	8	6	25	31	24
	75-80	25	27	15	23	18	20	14	15	11	17	21	26
	80-85	36	31	35	32	17	25	19	19	10	20	29	31
	85-90	27	31	26	40	38	21	25	23	21	18	40	30
	90-95	27	19	40	39	40	28	22	32	29	40	34	25
	95-100	21	19	28	37	41	39	28	46	41	39	25	19
	100-105	22	16	27	39	31	40	28	33	31	29	25	19
	105-110	20	18	18	20	27	13	8	8	16	8	25	12
	110-115	11	12	15	15	24	14	19	15	20	11	15	5
	115-120	5	8	12	11	15	3	6	9	14	8	5	4
	120-125	8	12	10	8	2	6	2	4	5	8	10	5
	125 130	3	3	6	2	------	1	0	0	0	2	4	5
35-40	65-70	5	2	4	2	1	2	1	2	0	5	0	4
	70-75	15	27	15	14	8	9	3	4	1	8	25	20
	75-80	15	21	15	20	15	13	5	5	3	6	17	21
	80-85	16	18	14	18	13	12	5	4	8	7	10	14
	85-90	22	35	24	20	12	13	5	8	±7	4	23	31
	90-95	27	30	28	28	21	16	8	12	13	14	37	41
	95-100	20	43	46	46	46	28	26	19	25	31	42	27
	100-105	35	44	49	64	46	32	18	18	26	12	37	25
	105-110	12	22	41	38	29	15	7	8	10	20	16	15
	110-115	15	24	21	23	24	6	8	2	8	15	10	14
	115-120	5	13	10	10	11	6	4	2	4	6	6	4
	120-125	3	6	6	2	0	1	0	4	2	3	3	2
30-35	70-75	5	16	2	2	0	1	1	0	0	4	6	2
	75-80	15	12	7	6	5	3	5	1	1	8	12	8
	80-85	9	15	14	12	7	6	7	1	4	6	17	9
	85-90	23	29	17	13	10	5	2	6	8	7	20	23
	90-95	30	35	20	16	11	5	3	6	7	5	22	31
	95-100	30	31	28	25	11	17	5	3	4	4	23	34
	100-105	21	24	19	13	15	2	+0	3	0	12	10	16
	105-110	6	19	12	13	15	2	0	0	0	7	6	12
	110-115	15	18	15	10	17	2	2	2	2	8	10	14
	115-120	5	6	2	2	2	0	0	0	0	1	2	2
	120-125	2	2	2	0	0	0	0	0	0	0	0	0
25-30	70-75	1	7	0	0	0	0	0	0	0	2	2	0
	75-80	3	3	0	1	4	0	0	1	0	7	2	0
	80-85	9	8	5	1	5	0	0	1	1	5	4	4
	85-90	12	13	3	3	1	2	2	2	7	4	4	10
	90-95	13	24	8	8	3	3	1	2	6	4	7	18
	95-100	35	33	25	13	8	2	0	0	5	9	13	34
	100-105	3	7	2	2	3	0	0	0	0	2	3	4

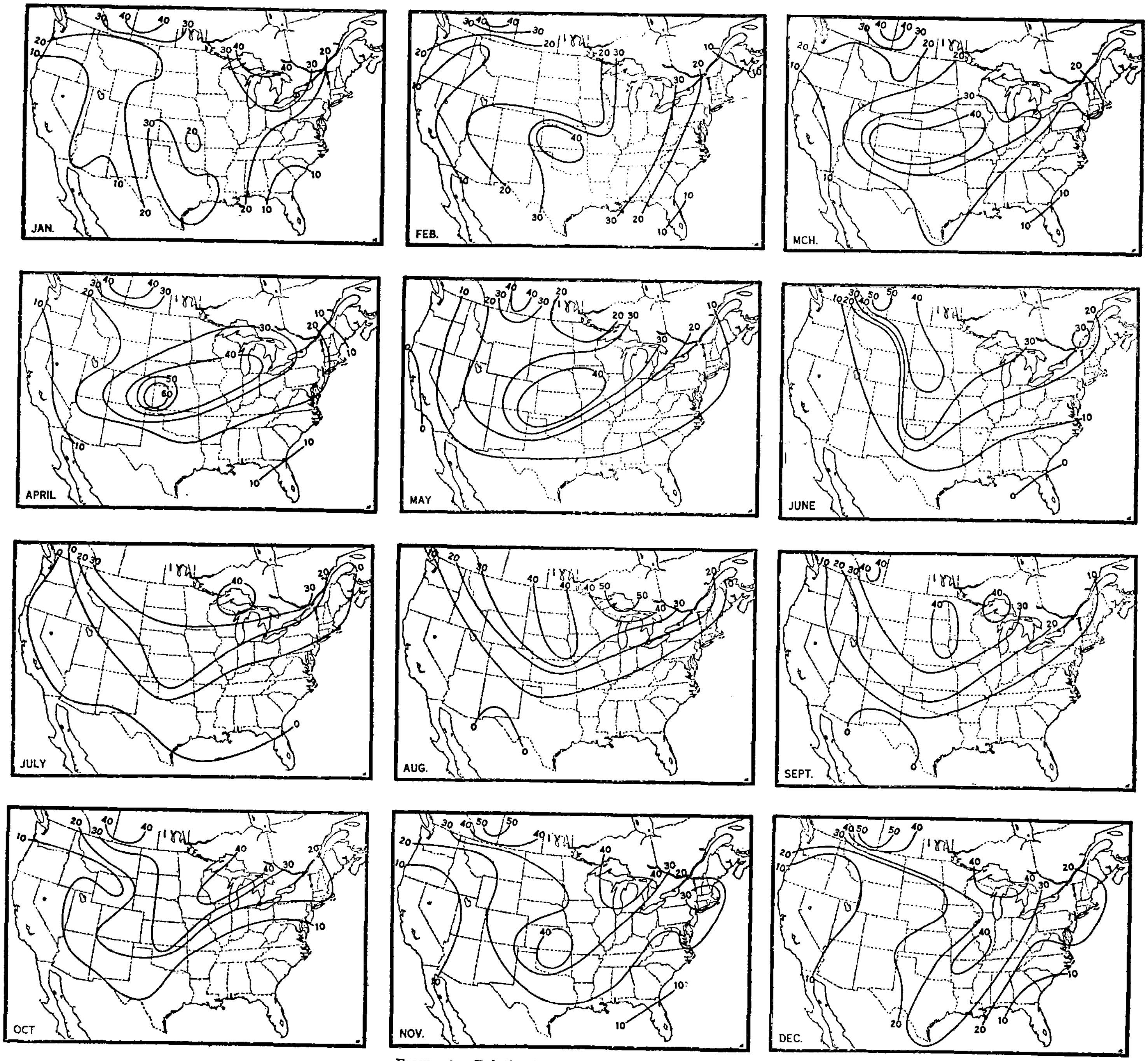

FIGURE 1.—Relative frequency of cyclones by months

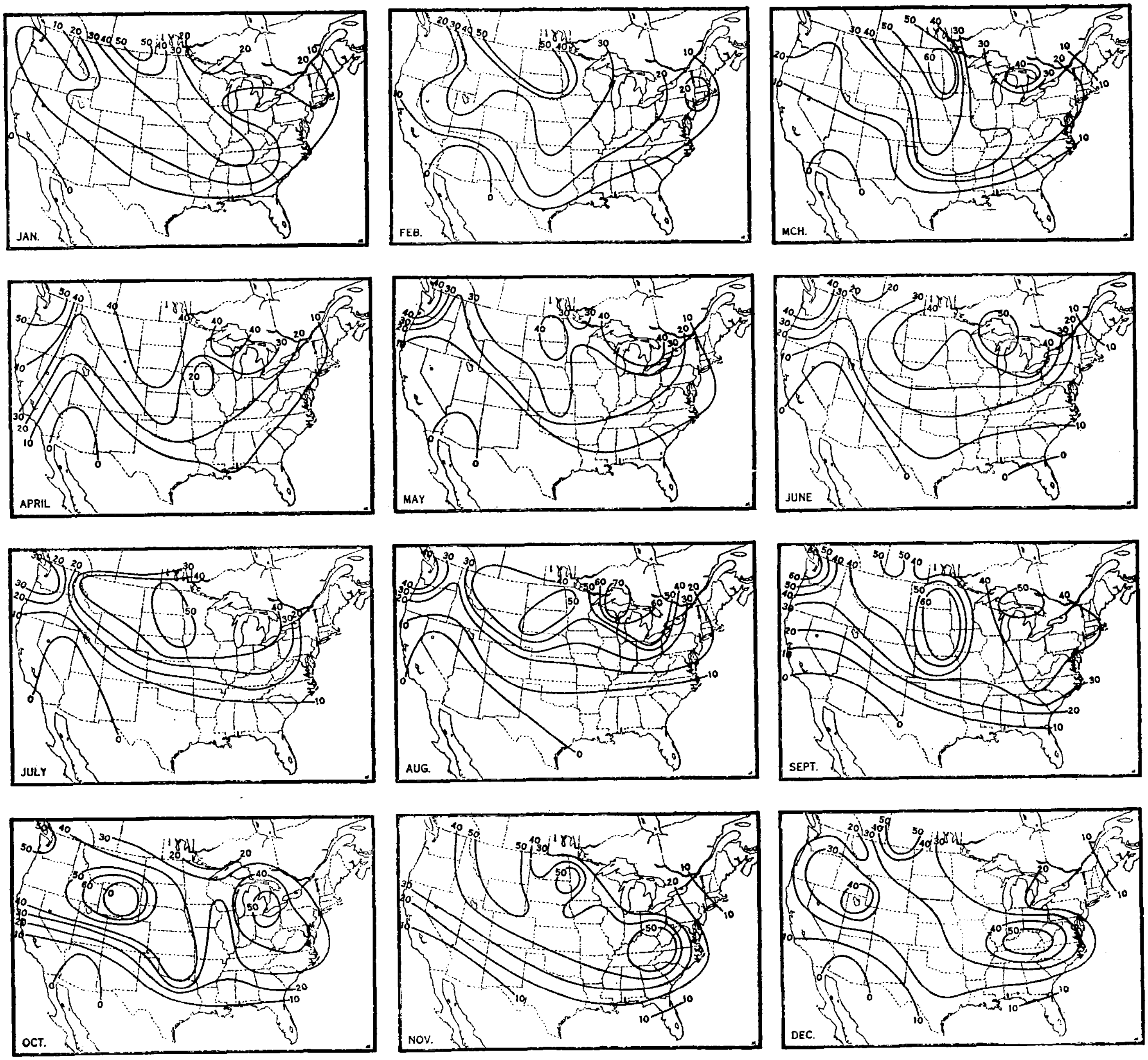

FIGURE 2.—Relative frequency of anticyclones by months

TABLE 2.—*Relative frequency of centers of anticyclones pro mille of observations per 5° square*

Latitude	Longitude	January	February	March	April	May	June	July	August	September	October	November	December
50°–55°	80°–85°	5	-----	1	4	4	3	0	1	2	7	0	2
	85–90	9	3	6	8	7	6	1	9	9	4	2	7
	90–95	5	9	11	14	8	4	5	5	8	6	5	10
	95–100	24	82	31	31	28	16	19	25	30	14	26	27
	100–105	41	33	41	24	36	21	24	28	31	21	28	33
	105–110	53	56	57	40	33	28	26	41	58	35	55	59
	110–115	47	51	47	32	32	22	26	38	46	35	54	40
	115–120	20	16	23	18	18	15	16	26	36	24	29	21
	120–125	4	3	2	3	3	4	8	20	14	5	5	5
45–50	60–65	-----	1	-----	-----	-----	2	-----	1	1	4	0	-----
	65–70	5	12	6	4	7	6	4	8	14	24	7	8
	70–75	16	9	8	5	8	5	6	12	23	21	10	13
	75–80	26	17	15	20	16	16	11	27	36	21	14	25
	80–85	25	25	42	39	41	44	26	61	53	49	24	26
	85–90	23	30	37	48	45	56	45	79	58	41	27	25
	90–95	12	24	21	25	25	36	29	43	29	24	30	21
	95–100	35	51	61	47	46	48	51	58	60	46	51	57
	100–105	31	48	43	39	35	47	48	48	43	42	40	36
	105–110	23	33	35	37	38	36	41	48	48	43	37	34
	110–115	10	18	25	35	28	30	42	40	44	47	51	15
	115–120	12	13	10	26	14	17	17	18	36	45	39	28
	120–125	11	12	23	58	41	47	36	45	63	54	37	18
	125–130	-----	3	12	32	25	24	22	22	32	19	7	2
40–45	60–65	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	65–70	2	3	2	2	7	10	1	9	17	8	5	4
	70–75	25	21	21	10	12	17	13	21	48	28	13	16
	75–80	11	18	21	13	20	20	19	36	42	35	13	22
	80–85	15	23	24	30	40	46	41	56	43	51	29	12
	85–90	14	22	21	24	28	38	41	36	35	27	25	23
	90–95	32	35	24	19	21	36	40	35	39	32	44	32
	95–100	32	32	45	36	38	36	56	44	61	47	36	31
	100–105	21	26	38	47	28	42	38	51	49	48	44	21
	105–110	23	23	22	27	34	34	18	31	39	75	57	25
	110–115	24	82	21	29	16	23	15	9	26	68	49	45
	115–120	16	25	15	15	5	8	8	2	21	42	45	37
	120–125	7	13	18	41	17	5	11	11	34	44	36	29
35–40	65–70	-----	-----	-----	-----	2	-----	-----	-----	-----	-----	-----	-----
	70–75	8	5	10	4	11	13	7	8	19	16	7	7
	75–80	18	13	12	7	12	11	15	19	32	41	38	39
	80–85	29	14	25	18	16	17	20	10	46	39	58	54
	85–90	30	24	33	28	23	16	25	10	32	38	50	50
	90–95	25	25	28	27	21	22	19	13	28	28	44	32
	95–100	27	30	43	36	33	19	18	14	25	41	44	82
	100–105	14	24	21	21	15	21	8	12	19	25	36	21
	105–110	19	17	8	10	5	5	5	2	6	16	33	22
	110–115	13	8	7	2	1	0	0	0	4	9	14	18
	115–120	8	4	4	2	2	0	1	0	1	4	11	18
	120–125	9	8	12	33	7	6	2	4	13	14	10	15
30–35	70–75	-----	-----	-----	-----	-----	-----	2	-----	-----	-----	-----	-----
	75–80	6	3	4	1	2	8	5	0	6	4	10	7
	80–85	6	5	6	8	3	2	3	2	9	7	17	16
	85–90	12	8	10	11	10	6	5	3	19	12	25	18
	90–95	13	13	12	6	5	6	2	4	9	17	23	23
	95–100	11	20	16	10	6	10	2	1	7	17	34	25
	100–105	6	10	12	9	3	3	2	0	2	12	17	13
	105–110	1	2	1	1	2	0	0	0	0	2	6	2
	110–115	1	0	0	0	0	0	0	0	0	0	1	0
	115–120	0	1	2	2	2	0	0	0	0	1	1	3
	120–125	-----	-----	-----	2	2	0	0	2	0	1	1	2
25–30	70–75	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	75–80	-----	-----	-----	-----	1	-----	2	0	0	0	-----	-----
	80–85	1	3	3	3	1	0	5	0	0	1	2	2
	85–90	1	3	3	3	2	2	1	0	2	0	2	5
	90–95	2	3	5	3	1	2	0	0	1	1	2	6
	95–100	5	8	3	4	2	0	0	0	2	1	13	15
	100–105	0	0	1	0	0	0	0	0	0	0	2	2

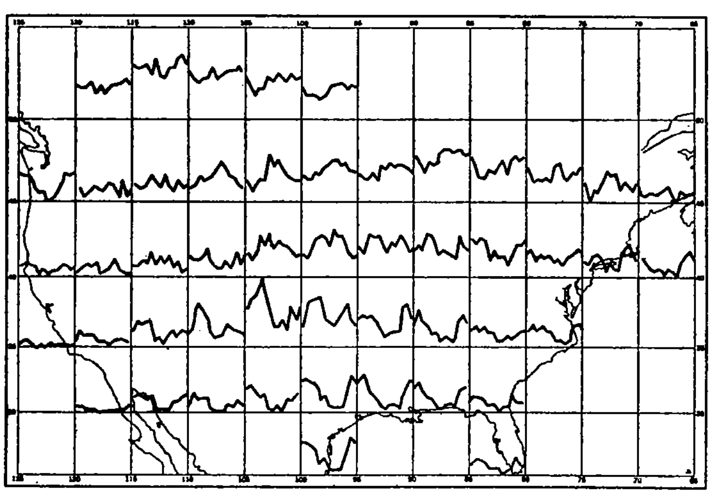

FIGURE 3.—Annual march of frequency of cyclone centers by 5° squares

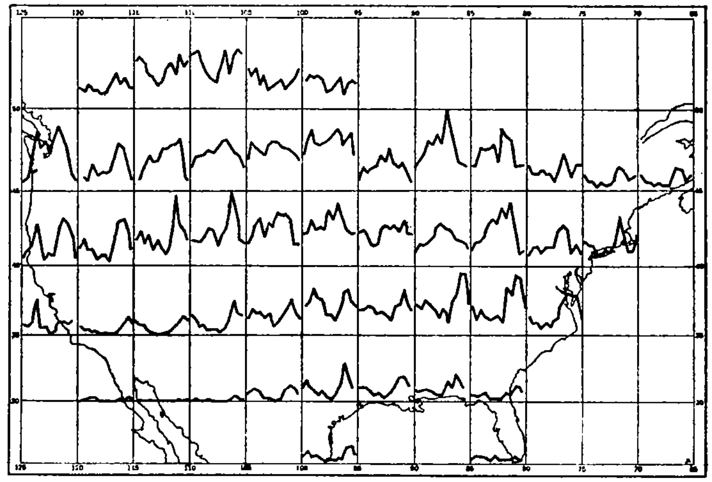

FIGURE 4.—Annual march of frequency of anticyclone centers by 5° squares

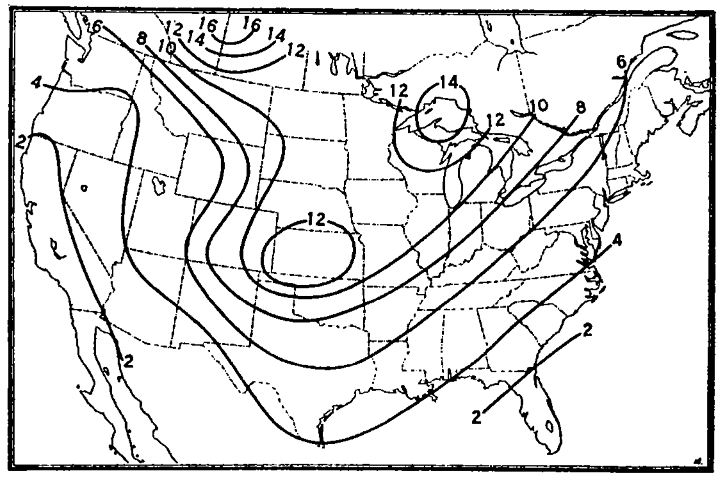

FIGURE 5.—Total number of cyclones per annum, on the average

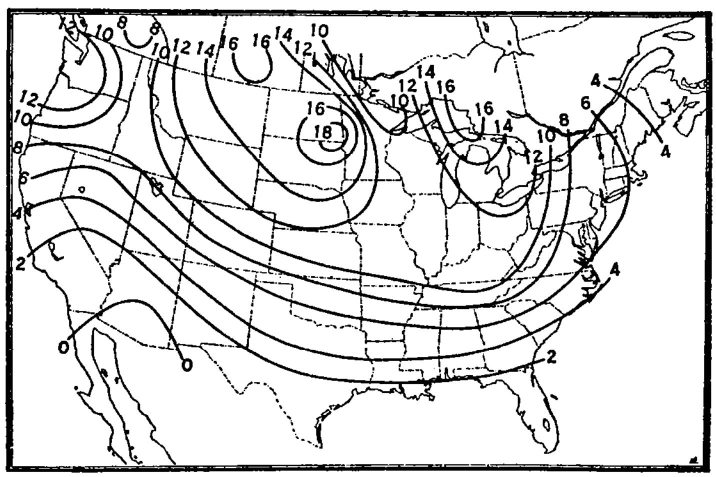

FIGURE 6.—Total number of anticyclones per annum, on the average

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INTERNATIONAL RESEARCH COUNCIL—THIRD REPORT OF THE COMMISSION APPOINTED TO FURTHER THE STUDY OF SOLAR AND TERRESTRIAL RELATIONSHIPS

By HERBERT H. KIMBALL

[Weather Bureau, Washington, February 3, 1932]

This important report is made up of 40 short papers by 44 different authors, on a great variety of subjects. Three of these are of special interest to meteorologists, as follows:

(1) Report on solar and terrestrial relationships, by C. G. Abbot. In this report the author anticipates some results that will be given in Volume V of the Annals of the Astrophysical Observatory, which is soon to be published, and which will summarize the work of the observatory to the end of the year 1930. Quoting from the report:

The principal features and many details of the sun's variation since 1918 are found to be the sum of five regular periodicities. Their periods are 65, 45, 25, 11, and 8 months. Their amplitudes are 0.014, 0.013, 0.010, 0.009, and 0.005 calorie, respectively. Between times when they all reinforce each other to increase the solar radiation and to decrease it, there is a range of 0.102 calorie, or about 5 per cent. This was not entirely reached at any time since 1918, the nearest approach of about 3 per cent occurring in 1922.

Superposed on this background of fairly permanent long-period periodicities are many periodicities and also irregular solar fluctuations of shorter intervals. Among these are sequences of solar change running their course upward or downward in a week or less. We are able to discriminate these with fair certainty if they exceed 0.45 per cent, by the daily observations of our best station, Montezuma. The other stations show sufficient evidence of correlation to establish a very strong probability of the veridity of these small changes, but have not sufficient accuracy or continuity to duplicate them all as we would like to see them do. However, the *temperatures* of Washington and other stations in the United States show so obvious a dependence upon these sequences of solar variation, discovered in the observations of Montezuma, Chile, as to be an independent verification of them.

(2) Relation of World Weather to solar radiation changes, by H. Helm Clayton.

The author refers to work begun by him in 1916 which showed a correlation between periodicities in weather changes and in solar activity as evidenced by both solar constant values and sunspot relative numbers. In the present paper he states:

The annual solar variation means show an 11-year period, but it is not the dominating period as in the case of sunspots. There are found instead marked oscillations of a few days in length, other oscillations of about 30 weeks, of about 5 months, of 8 months, of 11 months, of 22–28 months, 45 months, etc., which have amplitudes approximately as great as that of the 11-year period.

The temperature and pressure show similar oscillations, and it is of importance to note that these *terrestrial changes show a similarity to solar radiation changes and not to sunspot curves.*

The short periods found approximate to fractions of the 11.25 year sunspot period or the double sunspot period of 22.5 years. It is hence assumed that they are harmonics of this longer period.

For a summary of Clayton's paper we will quote the following paragraph:

MOVING WAVES OF WEATHER

The disentangling of solar influences is rendered very difficult by the discovery that following oscillations in intensity of solar radiation something in the nature of pressure and temperature waves are sent out from certain centers of action, more especially from the polar areas. These moving waves are the chief cause of weather changes. They progress with a velocity proportional to the length of the oscillation of the solar pulsation, that is, oscillations of short duration produce waves which move rapidly and oscillations of long duration produce waves which move slowly. The combined effect is the complex condition found on our weather maps.

In this paragraph the author has given a clear picture of the cause of weather changes in the *pressure and temperature waves sent out from certain centers of action, more especially the polar areas.* The attempt to connect these waves with *oscillations in intensity of solar radiation* requires observational proof, which at present is lacking, and especially as the waves are most pronounced at the season of the year when the polar region from which they appear to move is receiving no solar radiation.

(3) Ultraviolet solar radiation and its relation to the solar constant, solar activity, the ozone content, and the turbidity of the earth's atmosphere, by Walter E. Bernheimer.

In this paper we have the views of an astronomer on the question of solar-constant variations, as follows:

The recently published values of the solar constant make it possible to treat the material to April, 1931. The general march without secondary fluctuations, calculated in like manner as for the ultra-violet solar radiation, is shown in the upper part of Figure 2 (not reproduced). It will be seen that the solar constant reaches a maximum about half a year before sunspot maixmum. The minimum of the smoothed solar constant occurs in April, 1929; after that the values become successively higher, and reach nearly a maximum in the spring of 1931, while sunspot relative numbers in general are falling off from maximum to the approaching minimum in the solar cycle.

It seems therefore as though solar radiation were quite independent of solar activity. A direct comparison between the march of ultra-violet solar radiation and the solar constant * * * reveals a tendency somewhat fatal to the theory that both quantities are correlated and have a common physical source. If the reality of a fluctuation in the total and the ultra-violet radiation should be proved, much further work will be needed to find the cause for the strange fact that solar radiation measured in the main spectrum, and solar radiation measured in the short wave-lengths, manifest a quite different behaviour, and that the march of both quantities is obviously not related to the general variations of solar activity. We may also state that aurorae and terrestrial magnetism are the only phenomena which obviously vary in accordance with the solar activity.

During the polar year August, 1932, to August, 1933, inclusive, meteorologists and meteorological services of the world will unite in a study of meteorological conditions in both Arctic and Antarctic regions, with a view to determining their influence upon the weather in lower latitudes. The program includes solar radiation measurements, but hardly of the character that are required to measure solar variability, except as it is reflected in magnetic measurements. The work should, however, shed light upon the origin and movements of the great surges of air that move at frequent intervals from polar to equatorial regions, and vice versa, and which are the cause of the frequent and marked weather changes in middle latitudes.